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Review of Nanomedicine[1]

Review Article

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The field of nanomedicine holds vast potential for the improvement of health care around the world and the coming nanomedical revolution will surely bring innovative solutions to many of the difficulties we currently encounter in the realm of patient treatment. Nanomedicine is a relatively new field for scientific inquiry. It is defined as the use of nanoscale devices or materials to diagnose and cure diseases by actively interacting at the molecular level within a cellular system. In the context of nanotechnology, the "molecular level" refers to structures less than 100 nanometers in diameter. Given the breadth of this definition of nanomedicine, it can be narrowed and made more applicable when only those devices or medicines *designed* to function on the nanoscale are considered.

Nanorobotics, as its name suggests, is a discipline centered around robots constructed on the nanoscale. These robots could have many applications in the medical field and have the potential to drastically improve disease detection, drug delivery, immunization, and other forms of treatment. An important area of research is the development of nanorobots that can detect cancerous cells and subsequently execute a targeted delivery of cancer drugs. Current treatments such as chemotherapy indiscriminately attack all the cells in a given area and are therefore limited by the dosage of the drug that the patient's body can tolerate. In such cases, it is possible that this dosage will not succeed in entirely eliminating the cancer. The realization of targeted drug delivery using nanorobots would allow us to apply the necessary amount of a drug to a precise area without harming healthy tissue. In this way, nanorobots promise cancer treatments that are safer, less painful, and more effective than current treatments.

Researchers today are exploring organic, inorganic, and hybrid nanorobots. Organic nanorobots are based on adenosine triphosphate (ATP) and DNA molecular assembly and function. Another subset of organic nanorobots, based on bacteria, have been proposed experimentally for drug delivery. Inorganic nanorobots are essentially nano-electromechanical systems (NEMS). As technology has developed, some approaches have begun to combine both organic and inorganic elements, creating a more advanced robot system known as a hybrid nanosystem. The inherent programmability of inorganic nanorobots based on CMOS technology makes them the most likely to succeed in performing the complex, precise tasks required of medical nanorobots.

Some nanorobots currently being developed can detect cancerous cells by identifying biomarkers. There are currently a number of methods for identifying biomarkers. One method involves the nanoscale cantilever, which resembles an everyday comb (at the nanoscale). This structure is coated with antibodies designed to bind molecules produced by cancer cells. Adsorption of these molecules results in bending of the cantilever, a change which can be measured by optical or electrical means and can therefore be used by researchers to verify the presence of cancer. Other tools used to detect disease include nanowires, carbon nanotubes, quantum dots, and gold nanoparticles. These tools, like nanoscale cantilevers, are useful because they react in some measureable way to the presence of certain molecules.

Nanorobots have great potential not only for the detection of cancer cells but also for their elimination. Some methods of nanorobotic cancer treatment currently being explored do not rely on the use of traditional drugs. Gold nanoparticles and metal nanoshells can destroy cancerous tissues through thermal necrosis when they are heated through an external non-invasive heating source. Supermagnetic beads can penetrate and destroy cancer cells with the help of an applied magnetic field. Magnetic fields also continue to be explored as a way of directing the delivery of medication in the body. Other researchers are studying the ability of nanorobots to differentiate between normal and cancerous cells based on the presence of surface antigens such as E-cadherin.

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1. Preliminary short version of paper appears in the 6th Global Experts Meeting & Expo on Nanomaterials and Nanotechnology [1]
   A full version of the paper appears as a chapter in Wireless Computing in Medicine and Its Ethical/Legal Implications: From Nano to Cloud [2]
2. Authors listed alphabetically by last name, as opposed to order of contribution

In order for a treatment to be successful, nanorobots must be capable of more than just detecting and eliminating cancer cells; they have to be able to withstand the sometimes extreme conditions within the human body long enough to travel to the cancerous cells and deliver the medication. Therefore, biocompatibility, the ability of a material to perform with an appropriate host response in a specific situation, is extremely important in the development of nanorobots. A nanorobot that is not fully biocompatible may trigger unwanted immune responses when introduced into the body. Stimulation of the immune system, or *immunostimulation*, while sometimes desirable, can endanger the nanorobot, since it may be destroyed before it is able to complete its task. Immunostimulation can also be dangerous to the host, potentially inducing fever, inflammation, and hypersensitivity to allergens. Introducing a nanorobot into the body can also cause suppression of the immune system, or *immunosuppression*. Immunosuppression can be helpful for the nanorobot since a weakened immune system is less able to attack foreign bodies. At the same time, however, a weakened immune system increases the patient's vulnerability to viruses, bacteria, and infection. As nanorobots continue to improve, they will likely be most effective when they can enter the body without causing any disturbance of the immune system.

Although robots on the nanoscale are not yet being produced, we can use computer modeling to attempt to determine how various components will function once introduced into the body. Professor Eshaghian-Wilner's research group has created a basic computer model in ExtendSim that can be used to study the performance and biocompatibility of nanorobots and well as the toxicity of different drugs. The model is in its early stages and currently lacks experimental data, but has been designed in such a way that new data can be added to the simulation fairly easily for future improvement. Additional information regarding the current state of nanomedicine as well as its potential for the future can be found in this research group's recent publications [3-19].

As interest in nanomedicine builds, research institutions around the world are receiving increasing amounts of funding to explore and innovate in such areas as nanorobotics. Ushering in the nanomedical revolution will undoubtedly prove essential in raising the level of health care for people around the world.

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